Insect Science (2005) 12, 25−30

Development and reproduction of *Bemisia tabaci* (Homoptera: Aleyrodidae) on three bean species

PETER D. MUSA and SHUN-XIANG REN
Department of Entomology, College of Natural Resources and Environment, South China Agricultural University, Guangzhou, China

Abstract The development, survivorship and reproduction of *Bemisia tabaci* B-biotype on three bean species were studied at 26 ± 1℃ in the laboratory. The developmental periods from egg to adult varied from 27.80 days on garden beans to 18.20 days on soybeans. The survivorship from egg to adult on soybeans, cowpeas and garden beans was 77.14, 70.14 and 64.28%, respectively. The average longevity of female adults ranged from 12.30 days on soybeans to 9.80 days on garden beans, and the oviposition of *B. tabaci* varied from 160.85 eggs on soybeans to 98.00 eggs on garden beans. Life table parameters were calculated as biological attributes for *Bemisia tabaci* populations fed on three bean species. The results indicated that the intrinsic rate of increase (r_m), the finite rate of increase (λ) and net reproductive rate (R_0) were high for populations fed on soybeans, with values of 0.1857, 1.2041 and 82.1576, respectively. The corresponding values were less for populations fed on garden beans, with values of 0.1097, 1.1159 and 31.2661, respectively. The parametric values for cowpeas were intermediate between soybeans and garden beans but no significant difference were observed for the r_m values for soybeans and cowpeas. Experimental evidence in our investigation indicated that *Bemisia tabaci* is best adapted and shows the greatest preference for soybean of the three bean species tested in this study.

Key words *Bemisia tabaci*, development, reproduction, bean species
DOI 10.1111/j.1744-7917.2005.00004.x

Introduction

Grain legumes such as cowpea, garden bean and soybean, to name but a few, are widely cultivated in the tropics and sub-tropics of the world as a supplementary source of protein in the basic human diet, and are considered to play an important role in human nutrition. Their cultivation is therefore given much consideration compared with other vegetables and cereal crops. However, one of the most important constraints on grain legume yield is heavy biotic pressure from insect pests, including aphids, whiteflies, legume bud thrips, legume borers, pod-sucking bugs and storage bruchids. Among them, whiteflies have been observed to have devastating effects on crop yield.

The sweet potato whitefly *Bemisia tabaci* is a cosmopolitan pest with a worldwide distribution in different climatic zones ranging from tropical to temperate, in diverse ecosystems. The high reproductive potential, small size and high dispersal ability of this species are responsible for its pest status worldwide. Although 40 species of *Bemisia* have been described, only three species are of consequence as pests in annual cropping systems, and only a few species regularly cause damage in perennial ecosystems; two species, however, are of paramount importance (Byrne *et al.*, 1990). *Bemisia tabaci* is a significant pest, and it is considered a big threat to many crop growers by virtue of the damage caused.

Damage is caused by feeding on the phloem sap, which can result in stunted plant growth and reduced

Correspondence: Shunxiang Ren, Department of Entomology, College of Natural Resources and Environment, South China Agricultural University, Guangzhou 510642, China. Tel: +86 20 8528 2252; fax: +86 20 8528 0292; e-mail: rensxcn@yahoo.com.cn

yields, can lead to the induction of plant physiological disorders such as squash silver leaf and irregular ripening of tomatoes, and to the transmission of geminiviruses to a wide range of vegetable and field crops in various climatic zones.

The selection of simple demographic models such as life tables with clear biological content is an important step toward a better understanding of the biology and population dynamics of insect pests; knowledge that can be used subsequently as a tool in designing pest management strategies. This must involve a thorough understanding of the biological attributes of this pest with reference to development and reproduction on its host plants. This research was therefore designed to investigate the development and reproduction of *B. tabaci* fed on three bean species, in order to understand its biological attributes and potentially form a basis for sound pest management strategies.

Materials and methods

Insects and host plants

Sweet potato whitefly *B. tabaci* (Gennadius) were reared on cucumber plants in the greenhouse, which served as a stock colony. The fourth generation of this colony was used to infest the test materials.

Three bean varieties, namely soybean (*Glycine max*), garden bean (*Phaseolus vulgaris*) and cowpea (*Vigna unguiculata*) of the family Leguminoseae, were used in this study. The viable seeds were placed in Petri dishes soaked with water, and covered with cotton wool to facilitate sprouting. The sprouted seeds were established in plastic containers with well-manured sterilized soil and then confined in bioassay cages (60 cm × 60 cm × 60 cm) where they grew to three-leaf stage.

Development and survivorship

Fifty unsexed whitefly adults from the stock colony were used to infest the test materials for 24 hours for the oviposition of eggs. The whitefly adults were removed 24 hours later. The freshly-laid eggs were counted and served as cohorts on each of the bean varieties. The three species of bean plants were then placed in the growth chamber under control experimental conditions of 26 ± 1℃, a relative humidity of 70% ± 10% and an artificial photoperiod of 14 : 10 (L : D) h, respectively, to determine the development and survival of the nymphs. The numbers of hatched eggs and nymphs were counted and recorded daily under the microscope. Leaves bearing pupae were enclosed in Petri dishes, and the top was lined with nylon cloth for checking adult emergence and determining sex ratio.

Female adult longevity and fecundity

The newly emerged whitefly adults from the cohort populations were separated according to sex. Each female whitefly was confined in a micro cage, clipped to the undersurface part of the leaf and maintained in a bioassay cage (n=30). The bioassay cages were then kept in the same experimental conditions described above. The daily number of eggs oviposited and the life span of the female adults were recorded to calculate their fecundity and longevity, respectively. As a precaution to nullify the influence of honeydew secretion on egg oviposition, the test materials were replaced every two days.

Life table and demographic parameters

Life tables were calculated from the cohort eggs according to the method of Andrewartha and Birch (1954). The probability of surviving from birth (cohort eggs) to age x (l_x) for every immature stage was also calculated. The intrinsic rate of population increase (r_m) was calculated as follows:

$$T = \sum x l_x m_x / \sum l_x m_x ,$$
$$R_0 = \sum l_x m_x ,$$
$$r_m = \ln R_0 / T ,$$

where l_x is the survivorship at the corresponding time; m_x is the number of female eggs laid according to sex ratio laid per female per day; R_0 is the net reproductive rate defined by the mean number of female progeny produced by a single female during its mean life span.

$\lambda = \exp(r_m)$ is defined as the finite rate of increase.

$GT = \ln R_0 / r_m$ is the generation time defined as the mean period elapsing between the birth of the parents and the birth of the offspring.

$DT = \ln 2 / r_m$ is the doubling time defined as the time required for the population to double its size.

Data analysis

Developmental time and survivorship of eggs at each nymphal stage were calculated. Adult longevity and fecundity were analyzed among treatments of bean variety. Nonlinear regressions of longevity on fecundity were performed using SAS software (SAS Institute 1988).

All parameters were analyzed among treatments of bean varieties using the generalized linear model (GLM) procedure of SAS; means were separated by Duncan's multiple

range test after a significant F-test at $P = 0.05$ (SAS Institute 1988).

Results

Development time of B. tabaci

The longest incubation period occurred on garden beans, with a mean value of 5.25 ± 0.41 days. There were no significant differences in the incubation period on the three different host plants according to ANOVA. The average development time (egg–adult) was shortest for the cohort reared on soybeans (18.20 ± 0.40 days), and the longest period was recorded on reared on garden beans, (27.80 ± 0.85 days). The first and second nymphal instars fed on soybean had the shortest developmental duration with a value of 2.50 days (Table 1). Development time for the immature instars fed on garden beans was the longest of the three host plants. The development time of pupae on garden beans was significantly different from those fed on soybeans and cowpeas (Table 1).

Survivorship of B. tabaci

The survival rates for the egg and the nymphal stages were higher than those of the pupa in the three host species (Table 2). The eggs of *B. tabaci* reared on soybeans had the highest survival rate compared with those fed on cowpeas and garden beans in the two periods. The results show that 95.97% of the eggs deposited on the soybean host plant survived and transformed into the first instars. The percentage survivorship of eggs oviposited on cowpeas and garden beans was 91.36% and 88.85%, respectively. The survival rates for the nymphal stages in the three host plants are fairly high. The egg-adult survival rates for *B. tabaci* reared on soybeans, cowpeas and garden beans showed a significant difference at the 0.05 level, with values of 77.14%, 70.04% and 64.08%, respectively.

Longevity and fecundity of B. tabaci

Adult female longevity varied among the three host plant species (Table 3). The longest female longevity was for populations fed on soybeans, with a value of 12.30 ± 0.35 days. The shortest period was recorded for populations reared on garden beans, with a value of 9.80 ± 0.39 days, while the value for cowpeas was 11.70 ± 0.20 days.

Fecundity varied among the host species, with the highest fecundities observed on soybean host plants (160.85 ± 19.04 eggs). The lowest fecundity was observed on populations reared on garden beans (98.00 ± 13.02 eggs) (Table 3). Separation of means at the 0.05 level of significance by Duncan's multiple range test (DMRT) did not indicate any significant differences in the longevity of adult females reared on the three host species. However, a significant difference in fecundity was observed between garden beans and soybeans, and cowpeas and garden beans.

Figure 1 illustrated the fecundity and survivorship of *B. tabaci* reared on soybeans. No preoviposition period was observed; oviposition commenced 24 hours after adult emergence, fluctuated between the fourth and ninth days and declined sharply on the tenth day. Survivorship was high, and fairly constant up to the tenth day, then declined sharply.

When *B. tabaci* was reared on garden beans. No preoviposition period was observed. Oviposition was highest on the second, third and fourth days after adult emergence, followed by a sharp decrease, and fluctuations on the ninth and eleventh days.

All the female adult whiteflies used in the investigation survived up to the fifth day, then a decrease in survivorship was observed to occur in subsequent days (Fig. 2).

The fecundity and survivorship of *B. tabaci* reared on cowpeas was shown in Fig. 3. The highest oviposition rate was observed on the fifth day. The survivorship of female adults was fairly constant from the first to the ninth day,

Table 1 Development time of *B. tabaci* on three host plants.

Host plant	Developmental time (days) (Mean ± SE)						
	Egg	1st instar	2nd instar	3rd instar	4th instar	Pupa	Egg–Adult
Soybean	4.00 a (± 0.48)	2.50 a (± 0.48)	2.50 a (± 0.40)	2.75 a (± 0.40)	2.75 a (± 0.35)	3.75 a (± 0.25)	18.20 a (± 0.40)
Cowpea	4.50 a (± 0.64)	3.50 a (± 0.64)	2.75 a (± 0.70)	4.50 a (± 0.28)	3.00 a (± 0.62)	4.50 a (± 0.28)	22.70 a (± 0.62)
Garden bean	5.25 a (± 0.41)	3.30 a (± 0.28)	4.00 a (± 0.40)	4.00 a (± 0.64)	4.50 a (± 0.64)	6.75 b (± 0.47)	27.80 b (± 0.85)

Means in column with the same letter are not significantly different at 0.05 level (Duncan's multiple range test).

Table 2 Survivorship of *B. tabaci* on three host plants.

Host plant	Survival rates (% ± SE)						
	Egg	1st instar	2nd instar	3rd instar	4th instar	Pupa	Egg−Adult
Soybean	95.97 a (± 3.58)	94.05 a (± 3.08)	95.62 a (± 4.39)	96.95 a (± 4.21)	93.29 ab (± 4.35)	98.39 a (± 4.01)	77.14 a (± 2.18)
Cowpea	91.36 ab (± 3.39)	97.30 a (± 4.03)	99.25 a (± 3.37)	91.29 b (± 4.02)	89.16 b (± 3.21)	97.67 a (± 2.29)	70.04 b (± 3.37)
Garden bean	88.85 b (± 2.28)	94.99 a (± 2.78)	89.13 b (± 2.15)	94.08 ab (± 3.07)	97.39 a (± 3.09)	93.25 b (± 3.31)	64.08 c (± 2.29)

Means in a column with the same letter are not significantly different at the 0.05 level (Duncan's multiple range test).

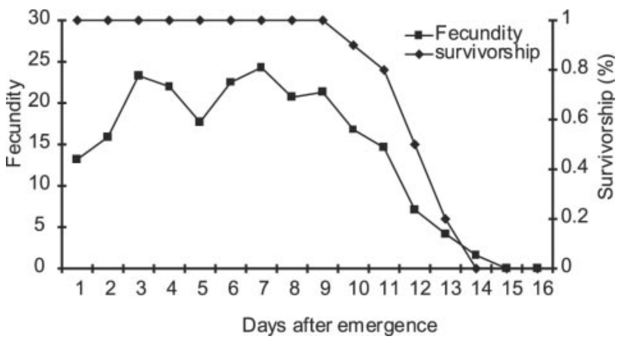

Fig. 1 Fecundity and survivorship of *B. tabaci* on soybean.

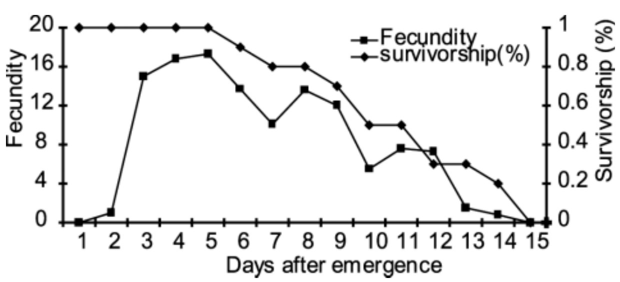

Fig. 2 Fecundity and survivorship curves of *B. tabaci* reared on garden bean.

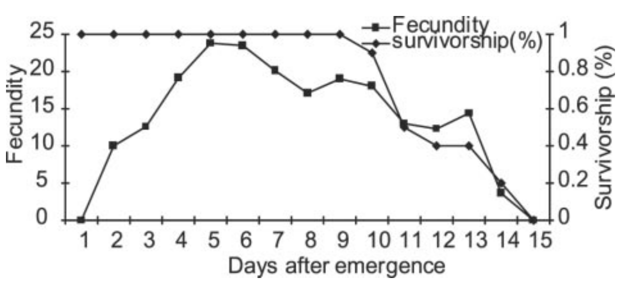

Fig. 3 Fecundity and survivorship curves of *B. tabaci* reared on cowpea.

with 100% survival of adults, then sharply decreased on the on the tenth day.

Regression analysis indicated that the fecundity of *B. tabaci* was independent of age. The fecundity patterns observed over the life span of whiteflies were best described by polynomial regression and formed a skewed-left pattern. One-way analysis of the number of eggs deposited according to host species showed significant differences ($F = 24.77$, df = 2, $P < 0.001$).

Life table demographic parameters

The demographic parameters calculated for the three host plant species in accordance with Birch (1948) showed variations among them. The net reproductive rate (R_0) of *B. tabaci* reared on soybeans, cowpeas and garden beans were 82.16, 48.58 and 31.26, respectively. The intrinsic rates of increase (r_m values) for soybeans, cowpeas and garden beans were 0.1857, 0.1547 and 0.1097, respectively. Futhermore, a significant difference in r_m values among cohorts was also observed ($P < 0.05$). The population reared on garden beans had a significantly lower value (0.1097) than the population reared on soybeans and cowpeas (0.1857 and 0.1547, respectively). The doubling times (DT) for soybeans, cowpeas and garden beans were 3.7326, 4.4816, and 6.3187 days, respectively (Table 4). The finite rate of increase (λ) was highest for soybeans and lowest for garden beans, with values of 1.2041 and 1.

Table 3 Longevity and fecundity of females of *B. tabaci* on three host plants (n=30).

Host plant	Longevity (± SE, days)	Fecundity (± SE, eggs)
Soybean	12.30 ± 0.35 a	160.85 ± 19.04 a
Cowpea	11.70 ± 0.20 a	153.07 ± 15.65 a
Garden bean	9.80 ± 0.39 a	98.00 ± 13.02 b

Means in a column with the same letter are not significantly different at the 0.05 level (Duncan's multiple range test).

Table 4 Life table parameters of *B. tabaci* on three bean species.

Host plants	Intrinsic rate of increase (r_m)	Finite rate of increase (λ)	Net reproductive rate (R_0)	Doubling time (DT, days)	Generation time (GT, days)
Soybean	0.1857	1.1204	82.1576	3.7326	23.7357
Cowpea	0.1547	1.1673	48.5839	4.4816	25.1075
Garden bean	0.1097	1.1159	31.2661	6.3187	31.3819

1159, respectively, and with cowpea (1.1673) intermediate between them. Generation time (GT) varied among the host plant species, with the shortest occurring on soybeans at 23.7 days compared to cowpeas at 25.1 days and garden beans at 31.3 days (Table 4).

Discussion

Plant species differ greatly in terms of their suitability as hosts for specific insects when measured in terms of insect survival and reproductive rates. Van Lenteren and Noldus (1996) state that a shorter development time and a greater total reproduction on a host indicate that a plant is a suitable host. In our investigation we found out that there is a strong relationship between oviposition preference and larval performance of *B. tabaci* populations reared on the three host species. *B. tabaci* appeared to be well adapted to develop on soybeans compared to the other two host plant species based on the various life-history measurements. The survivorship and incubation period of *B. tabaci* on soybean, as well as their development times were all shorter than those on cowpeas and garden beans.

Many researches have documented the effects of host plants on fecundity. Nava-Camberos *et al.* (2001) reported that a population of *B. tabaci* fed on cantaloup had a mean daily fecundity range of 8.3 ± 1.5−19.0 ± 2.5 eggs. They also showed that the mean daily number of eggs per female on cotton ranged from 5.8 ± 1.1 to 12.7 ± 1.8 compared to 1.0 ± 0.2 on pepper. The differences in r_m among the cohorts studied on bean species were due to differences in adult pre-reproductive periods, fecundity and generation times. Net reproductive rate differences among cohorts or populations of *B. tabaci* may have been the result of host-plant effects.

The *B. tabaci* cohorts that fed on soybeans and cowpeas showed higher intrinsic rates: faster development, higher survivorship, and higher oviposition rates than those fed on garden beans, these two species are presumably more suitable hosts for *B. tabaci*. Qiu *et al.* (2002) stated that the r_m values for *B. tabaci* on collard, eggplant, tomato, and cucumber were 0.1241, 0.1416, 0.1278, and 0.1143, respectively. They suggested that the life table parameters are strongly influenced by host plants. Their studies indicated that populations of *B. tabaci* fed on eggplant had the highest intrinsic rate of natural increase over the other host plants. High values of r_m indicate susceptibility of a host plant to insect attacks, while a low value indicates that the host-plant species is resistant to attack. Birch (1948) stated that r_m is perhaps the best single statistic for evaluating the influence of ecological factors on population growth. The results on demographic parameters derived from this investigation indicate that *B. tabaci* has the highest intrinsic rate of increase on soybeans compared with cowpeas and garden beans.

Acknowledgements

This research was supported by grants from the National Science Foundation of Guangdong Province (010312) and the National Tenth Five Research Plan for the Key Program (2001BA509B0604).

References

Andrewartha, H.G. and Birch, L.C. (1954) *The Distribution and Abundance of Animals*. Chicago University Press, Chicago.

Bellows, T.S., Perring, T.M., Gill, R.G. and Headric, D.H. (1994) Description of species of *Bemisia tabaci* (Homoptera: Aleyrodidae) infesting North America Agriculture. *Annals of the Entomological Society of America*, 87, 195−206.

Birch, L.C. (1948) The intrinsic rate of natural increase in an insect population. *Journal of Animal Ecology*, 17, 15−26.

Brown, J.K. (1994) Current status of *Bemisia tabaci* as a plant pest and virus vector in agroecosystems worldwide. *FAO Plant Protection Bulletin*, 42, 1−32.

Brown, J.K., Perring, T.M., Cooper, A.D., Bedford, I.D. and Markham, P.G. (2000) Genetic analysis of *Bemisia* (Homoptera: Aleyrodidae) populations by isoelectric focusing electrophoresis. *Biochemical Genetics*, 38, 14−25.

IITA (1997) Factors limiting food production in the sub-Sahara region. *Crop Protection Bulletin Annual Report*, 47, 48−52.

Krebs, Y. (1994) A new method of analyzing population growth. *Research of Population Ecology*, 11, 1−5.

Lenteren, J.C. and Noldus, L.P.J. (1990) Whitefly-plant

relationship: behavioral and ecological aspects. *Whiteflies: their Bionomics, Pest Status and Management* (ed. D. Gerling), pp. 47−89. Intercept, Andover, Hants, UK.
Nova-Cameros, B.A., Lewis, F.G. and Allen, D.K. (2001) Host selection and Specificity. *Biological Control*, 8, 211−216
Qiu, B.L., Ren, S.X., Sun, T.X. and Lin, L. (2002) Investigation of host plants of *Bemisia tabaci* (Homoptera: Aleyrodidae) in Guangzhou area. *Journal of South China Agricultural University*, 22, 43−47 (in Chinese).
SAS Institute (1988) *SAS/STAT User's Guide, release 6.03 edition*. SAS Institute, Cary, NC.
Taylor, L.R. (1984) Assessing and interpreting the spatial distribution of insect population. *Annals of the Entomological Society of America*, 29, 321−357.
Yokomi, R.K., Hoelmer, K.A. and Osborne, L.S. (1990) Relationship between the sweetpotato whitefly and squash silverleaf disorder. *Phytopathology*, 80, 95−100.

Accepted September 21, 2004